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Optimisation of Solar Collector's Efficiency using Copper Tube

Md. Tauqir Akhtar[1], Somvir Arya[2]

[1]*Research Scholar, Mechanical Engineering Department, Indus Institute of Engineering & Technology, Kinana (Jind) INDIA*
[2]*Assistant Professor & Head, Mechanical Engineering Department, Indus Institute of Engineering & Technology, Kinana (Jind) INDIA*

Abstract – *The country's solar installed capacity reached 25.21 GW as of 31st December 2018. India has just 5% of world solar capacity, while china has 33%. By using copper tube filled with pebbles efficiency of solar collector is increased by about 6%. Convection losses are reduced and a significant increased of heat transfer rate is obtained for the solar energy sector to grow at a steady clip, India must ensure consistencies in its policies. Not only is solar sustainable, in some cases it is cheaper than thermal power. It is said that solar will account for three-fourth of the renewable energy capacity in india in near future.*

***Key Words*: Parabolic, Collector, Copper, Absorber tube, temperature, pebbles etc**

1. INTRODUCTION

The demand of energy is increasing rapidly but resources are limited in nature. In India 70-75% village population are dependent upon conventional source of energy. Use of conventional source of energy causes evolution of poisonous gasses and it pollutes the environment. To avoid global warming, renewable source of energy is preferred nowadays. Sunlight energy is abundant in nature. We will work out how we can use this source of energy for our purpose. Our country is enriched with very vast resource of solar energy. Nowadays designing of energy efficient apartment/ building based on solar energy concept is an important emerging trend.

Application of Solar energy

1. Solar pumping

2. Solar heating of building

3. Solar water heating

4. Air conditioning and refrigeration

5. Solar desalination

6. Solar drying

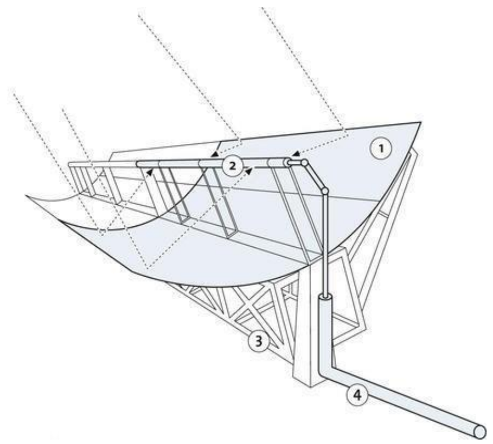
7. Heat of air for various purposes

8. Solar electric power generation

9. Solar cooking

Parabolic trough solar collector:-

Parabolic trough solar collector uses aluminium or mirror foil sheet in the shape of a parabolic cylinder to concentrate and reflect sun radiation towards a receiver take fixed at the focus line of the parabolic cylinder.



1. Reflector surface
2. Absorber tube
3. Supporting stand
4. Liquid inlet and outlet pipe

Fig. Schematic diagram of Parabolic Trough Concentrator

Some important definitions:

The aperture (w): Aperture is the place opening of the concentrator through which the solar radiation posses through. Its characteristics is determined by the diameter or width of the opening.

Intercept factor (r) : The fraction of the radiation which is refracted or reflected from the concentrator and is incident on the absorber. The approximated value of the intercept factor is equal to unity.

Acceptance angle: The angle over which beam radiation deviate from the normal toward the aperture plane.

Concentration ratio: It is the ratio of the effective area of the aperture to the surface area of the absorber. Concentration ratio value ranges from unity to a few thousand. Concentration ratio is also known as geometric concentration ratio.

2. Literature

John Ericsson constructed the first known parabolic trough collector in 1880. In 1907, the Germans Wilhelm Meier and Adolf Remshardt obtained the first patent of parabolic trough technology. India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. India was the first country in the world to set up a ministry of non-conventional energy resources, in early 1980s.

Seluck M. [8] [1979] investigated the thermal performance of the vacuum tube receivers with and without reflectors. Using vacuum tube with reflectors, the value of heat loss coefficient (UL) was reduced. This was resulted in the increased incident flux on an absorber tube and increased its thermal performance.

Rabl A. [7] et al. [1982] calculated the performance and optimized the design of parabolic trough solar collector. They optimized the different collector parameters like rim angle, concentration ratio and intercept factor.

Prapas D.E. [6] et al. [1987] analyzed optical behavior of parabolic trough collectors, based on a ray-tracing technique. The effects on the collector performance were studied by varying angular distribution of the diffuse isolation, scattering of the direct isolation by a transparent aperture cover and the total optical error of the concentrating system. They concluded that the amount of diffused radiations collected were negligible for parabolic trough collectors with high concentration ratio (C.R.>10).

Thomas A. [10] [1992] experimentally studied the solar steam generation system (parabolic trough collector) that generated steam at a temperature of 150ºC. The average daily efficiency of the system was 33.5%.

Fend Thomas [2] et al. [2000] used highly reflective aluminium coil for solar concentrators. Experiments were conducted using standard commercial anodized aluminium sheet of different thickness. They found that highly specular aluminium had an excellent chance to meet the trough requirements.

Bakos [1] et al. [2001] studied analytically the parabolic trough collector, due to their ability to work at high temperatures with high efficiency. The results produced from a simulation program, showing the variation of collector's efficiency as a function of heat transfer fluid flux, pipe diameter, solar radiation intensity and active area of the parabolic trough collector were presented.

Li and Wang [4] [2006] investigated the two types of solar evacuated tube to measure their heating efficiency and temperature with fluids of water and nitrogen gas. It was found that water temperature at 90-100ºC provide the better efficiency about 70% with both evacuated tubes. For the high temperature application with ammonia, the efficiency of solar concentrating system with evacuated tube collector decreased to 40%.

Jin [3] et al. [2012] investigated the operational performance and energy conversion efficiency of a developed 15 kW solar chemical receiver/reactor for hydrogen production. Solar receiver/reactor was tested at 200-300°C. They found that the solar thermo-chemical process was feasible at this temperature level.

Xiao Gang [11] [2007] studied a closed parabolic trough solar collector in which a hermetic box with a transparent cover and the parabolic reflector forming the back parabolic trough concentrated solar collector. And the tracking of the sun is done by rotating (swinging) the box around the receiver tube which is fixed with respect to the ground. The absorber is build by two concentrating tube such that outer glass tube and an evacuated annular space between the working fluid and outer glass tube, for the purpose of thermal isolation with a steel inner tube conducting the HTF, and an outer tube for air tightness. The interior of the boxes can be filled to a slight overpressure (50Pa or so), with air or gas supplied by a central equipment due to prevent the dust from the surroundings and subsequent damage to the optic surfaces. Active carbon can be used to remove most of the gaseous pollutants. Accepting an optical loss of a few percentages due to reflections by the cover, this design offers several advantages over the current open model, in particular a potential of significant cost reduction.

Laing Doerte [5] et al. [2006] conducted experiment in which using synthetic oil as the heat transfer medium and solid media sensible heat storage in solar parabolic trough. Two different storage materials have been used (a) castable ceramic as an innovative storage material (b) a high temperature concrete. Both materials are basically composed of a binder system. They find that high temperature concrete seems to be the more favourable material due to lower costs, higher material strength and easier handling maximum temperatures of 390°C have been developed. The thermal energy is provided by a parabolic trough loop with a maximum thermal power of 480 kW. Using a tubular heat exchanger which is integrated into the storage material regarding investment and maintenance costs.

Singh S.K. [9] et al. [2012] designed and fabricates the solar parabolic trough water heater for hot water generation. Aluminium sheet is used for making parabolic trough concentrator which is covered by a cloth on which rectangular mirror strips. Two different absorber tubes were taken and the efficiencies of the plate were compared without glass cover on the absorber tubes. The efficiencies find that when without glass cover: aluminum tube receiver: 18.23%, copper tube receiver 20.25%.

2.1 Problem formulation:

Solar air heater are considered to be the poor convective heat transfer co-efficient from absorber to the air. Because of the low heat transfer co-efficient it has relatively higher absorber plate temperature which causes more thermal losses to the environment and it leads to less thermal efficiency. Hence, it is very necessary to improve convective heat transfer co-efficient to increase the thermal efficiency of solar air heaters.

2.2 Methodology

Parabolic trough solar collector is fabricated initially. After that it is tested at KIET, Ghaziabad for hours under clear sunshine and the results are analysed to improve its performance with different absorber takes.

3. Result and Discussion

Table 3.1: Measured data with copper absorber tube at air flow rate i.e. 28.5 kg/hr

Time (hrs)	Solar radiation (W/m^2)	Ambient Temp. (°C)	Inlet air Temp. (°C)	Outlet air Temp. (°C)	Temperature difference (°C)	Thermal Efficiency (%)
1000	650	32	33.2	39.4	6.2	9.45
1100	780	34	36.1	44.6	8.5	10.73
1200	940	40	42.5	56.5	14	14.93
1300	900	41	43.9	60.9	17	17.45
1400	820	42	43.1	60.1	17	21.59
1500	680	40	40.3	51.4	11.1	19.19
1600	500	39	39.4	49.3	9.9	17.77
1700	300	35	36.2	42.3	6.1	18.3

Table 3.1 shows the reading of inlet air temperature. Inlet air temperature and ambient temperature after the end of absorber tube made of copper alone. From the figure it is clear that the maximum outlet temperature is obtained at 13:00 hrs. Maximum outlet temperature is at 13:00 hrs because solar radiation falls on collector perpendicular on the trough and most of the radiations are collected at given length of absorber. Minimum temperature is at 09:00 hrs and it increases gradually till 13:00hrs. After 13:00 hrs the temperature decreases gradually because of the fall in solar radiations. The maximum difference in rise in temperature is obtained as 17°C.

Table 3.2: Measured data with Copper Tube with pebbles at air flow rate i.e. 28.5kg/hr

Time (hrs)	Solar radiation (W/m^2)	Ambient Temp. (°C)	Inlet air Temp. (°C)	Outlet air Temp. (°C)	Temperature difference (°C)	Thermal Efficiency (%)
1000	680	32	34.1	40.7	6.6	9.32
1100	760	35	37.2	46.5	9.3	11.74
1200	910	40	42.5	57.8	15.3	16.14
1300	900	43	47.8	64.5	16.7	17.81
1400	840	43	43.9	64.1	20.2	23.08
1500	640	42	41.8	55.8	14	20.99
1600	560	39	40.3	51.7	11.4	19.54
1700	360	35	35.4	43.4	8	21.33

Table 3.2 shows the reading of inlet air temperature and outlet air temperature after the end of absorber tube made of upper and filled with pebbles. This setup will increase the maximum air temperature about 20°C_o and this is higher than by using absorber made of copper tube only.

4. CONCLUSION

- Convection losses are reduced when we use ETC tube and more temperature increase in heated air is obtained, which is about 23.5^0 C as compared to other cases.
- *Using* copper tube filled with pebbles and ETC tube as an absorber increases the efficiency about 6 percent. It can also be concluded that a significant increase of heat transfer rate could be obtained from ETC tube and packed bed solar air heater.

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